NACA

RESEARCH MEMORANDUM

TWO-DIMENSIONAL WIND-TUNNEL INVESTIGATION OF MODIFIED
NACA $65_{(112)}$-111 AIRFOIL WITH 35-PERCENT-CHORD SLOTTED FLAP
TO DETERMINE OPTIMUM FLAP CONFIGURATION AT
REYNOLDS NUMBER OF 2.4 MILLION

By

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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TWO-DIMENSIONAL WIND-TUNNEL INVESTIGATION OF MODIFIED NACA $65_{(112)}$-111 AIRFOIL WITH 35-PERCENT-CHORD SLOTTED FLAP TO DETERMINE OPTIMUM FLAP CONFIGURATION AT REYNOLDS NUMBER OF 2.4 MILLION

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SUMMARY

An investigation has been made in the Langley two-dimensional low-turbulence tunnel to develop the optimum configuration of a 0.35-chord slotted flap on an NACA $65_{(112)}$-111 airfoil section modified by removing the trailing-edge cusp. The results of the investigation indicate that for the optimum configuration at a Reynolds number of 2.4×10^6, the flap deflection was 45° and the flap leading-edge radius center was 0.73 percent-chord behind and 4.46 percent-chord below the slot lip. The maximum section lift coefficient for the optimum configuration at a Reynolds number of 2.4×10^6 was 2.46 or 0.12 higher than that obtained for an NACA 65-210 airfoil section with a 0.250-chord slotted flap.

INTRODUCTION

The modern high performance airplane with its increased wing loading requires the use of thin wing sections equipped with high-lift flaps. Experimental investigations, such as those reported in reference 1, have been made to develop 0.250-chord slotted flaps suitable for use on thin airfoil sections. Such investigations, however, have been made for only a small range of Reynolds numbers, (2.4×10^6 to 9.0×10^6), and a very limited amount of data for Reynolds numbers greater than 9.0×10^6 are available for thin airfoils equipped with slotted flaps. From data presented in reference 1, it is seen that large changes in the lift characteristics of a thin airfoil with a slotted flap may occur as the Reynolds number is increased. Some question also exists as to whether or not a flap configuration that is the optimum for high lift at low Reynolds numbers is still the optimum configuration at much higher Reynolds numbers.

An investigation is therefore being conducted in the Langley two-dimensional low-turbulence tunnels in order to develop the optimum configuration of a 0.35-chord slotted flap on a modified NACA $65_{(112)}$-111 airfoil section and to determine whether or not the developed optimum flap configuration is dependent upon the Reynolds number. Measurements to determine the section pitching-moment characteristics, the effects of leading-edge roughness on the lift characteristics, and the lift characteristics for the flap deflected through a developed flap path are also included in this investigation.

This paper presents the results of the first phase of the investigation, which covered the development of the optimum flap configuration at a Reynolds number of 2.4×10^6 in the Langley two-dimensional low-turbulence tunnel.

SYMBOLS

α_o section angle of attack, degrees

c airfoil chord

c_l section lift coefficient

$c_{l_{max}}$ maximum section lift coefficient

R Reynolds number

x, y horizontal and vertical positions, respectively, of the flap leading-edge radius center with respect to upper lip of slot in percent c, positive forward of and below slot lip, respectively (fig. 1)

δ_f flap deflection, degrees, angle between airfoil chord line in flap retracted position and airfoil chord line in flap deflected position (fig. 1)

MODEL AND TESTS

The 2-foot chord model tested in this investigation was a modified NACA $65_{(112)}$-111 airfoil section with a 0.35c slotted flap. The airfoil section had been modified by removing the trailing-edge cusp and was therefore similar to an NACA $65_{(112)}$A111 airfoil section. Ordinates for the plain airfoil section and the slotted flap are given in tables 1 and 2, respectively. Figure 1 is a sketch of the airfoil and flap and also shows the reference points defining the flap position. The model was constructed of aluminum alloy and completely spanned the 3-foot wide tunnel test section. The flap was attached to the main portion of the model by fittings at the ends which permitted independent variation of the flap position and deflection.

Measurements to obtain the maximum section lift coefficients for an extensive range of flap positions for flap deflections of 35°, 40°, and 45° were made in the Langley two-dimensional low-turbulence tunnel at a Reynolds number of 2.4×10^6. The range of flap positions investigated was sufficiently extensive to define the optimum configuration (the configuration for highest maximum lift) for each of the flap deflections tested. The test methods and the methods used in correcting the test data to free-air conditions are discussed in reference 2. The magnitude of the corrections used in correcting the test data to free-air conditions was of the order of a few percent. The maximum free-stream Mach number attained during any of the tests was approximately 0.16.

RESULTS AND DISCUSSION

Contours of values of maximum section lift coefficient for various positions of the flap leading-edge radius center with respect to the slot lip are presented in figure 2 for flap deflections of 35°, 40°, and 45°. These data indicate that at the optimum configuration, the flap deflection is 45° with the flap leading-edge radius center located 0.73 percent c behind and 4.46 percent c below the slot lip. The section lift characteristics of the optimum configuration for each of the flap deflections tested are presented in figure 3. From the data presented in figure 3, it is seen that at flap deflections of 40° and 45° and at angles of attack slightly below the stall, the slopes of the lift curves are considerably larger than the slopes at low angles of attack. Tuft studies of the air flow over the flap for these deflections indicated that the flap was stalled over most of the angle-of-attack range but unstalled a few degrees before the maximum lift coefficient was reached. A comparison of the lift characteristics for two flap positions at a flap deflection of 40° indicates that a more linear lift curve can be obtained for this flap deflection although the maximum section lift coefficient is somewhat less than that obtained for the optimum configuration (figs. 2 and 3). The highest maximum section lift coefficient was 2.46 or 0.12 higher than that reported for a 0.250c slotted flap (slotted flap 1) on an NACA 65-210 airfoil section (reference 1).

CONCLUSIONS

The results of tests of a modified NACA $65_{(112)}$-111 airfoil section with a 0.35-chord slotted flap indicate the following conclusions.

1. For the optimum configuration at a Reynolds number of 2.4×10^6 the flap deflection was 45° and the flap leading-edge radius center was 0.73 percent-chord behind and 4.46 percent-chord below the slot lip.

2. The maximum section lift coefficient obtained for the optimum configuration at a Reynolds number of 2.4×10^6 was 2.46 or 0.12 higher than that obtained for an NACA 65-210 airfoil section with a 0.250-chord slotted flap.

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REFERENCES

1. Cahill, Jones F.: Two-Dimensional Wind-Tunnel Investigation of Four Types of High-Lift Flap on an NACA 65-210 Airfoil Section. NACA TN No. , 1947.

2. Abbott, Ira H., von Doenhoff, Albert E., and Stivers, Louis S. Jr.: Summary of Airfoil Data. NACA ACR No. L5C05, 1945.

TABLE 1

ORDINATES FOR THE MODIFIED

NACA $65_{(112)}$-111 AIRFOIL SECTION

[Stations and ordinates given in percent airfoil chord]

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.463	.871	.538	-.821
.708	1.050	.792	-.979
1.204	1.325	1.292	-1.217
2.450	1.813	2.550	-1.625
4.942	2.546	5.054	-2.229
7.442	3.117	7.558	-2.696
9.942	3.600	10.058	-3.083
14.942	4.371	15.054	-3.700
19.950	4.958	20.050	-4.163
24.958	5.404	25.042	-4.508
29.967	5.725	30.033	-4.754
34.975	5.933	35.025	-4.904
39.983	6.033	40.017	-4.963
44.992	6.000	45.008	-4.904
50.000	5.829	50.000	-4.725
55.008	5.508	54.992	-4.413
60.017	5.087	59.983	-4.017
65.021	4.575	64.979	-3.546
70.025	4.029	69.975	-3.054
75.025	3.429	74.975	-2.533
80.025	2.792	79.975	-1.996
85.025	2.146	84.975	-1.471
90.021	1.483	89.979	-.967
95.017	.796	94.983	-.479
100.004	.054	99.996	-.054
L.E. radius: 0.842			

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TABLE 2

ORDINATES FOR 0.35-CHORD FLAP

[Lower surface of flap formed by lower surface of plain airfoil. Stations and ordinates given in percent airfoil chord]

Station	Ordinate
65.50	-0.863
66.00	-.367
67.00	.308
68.00	.792
70.00	1.442
72.00	1.846
74.00	2.104
76.00	2.267
78.00	2.346
80.00	2.354
82.00	2.300
84.00	2.183
86.00	2.000
Upper surface fairs into plain airfoil section at station 88.00	
L.E. radius: 1.404 L.E. radius center at station 66.50 and ordinate -1.971	

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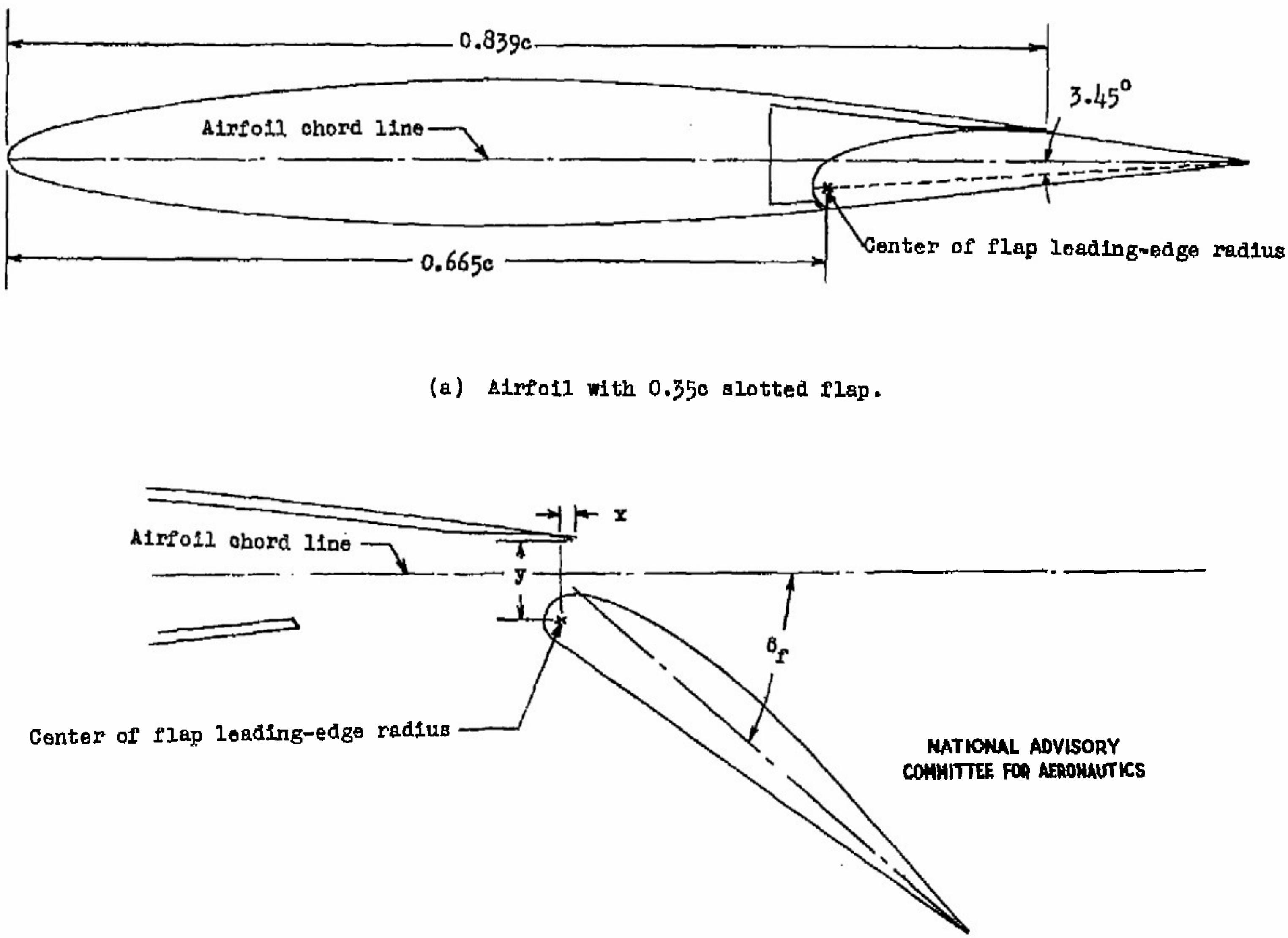
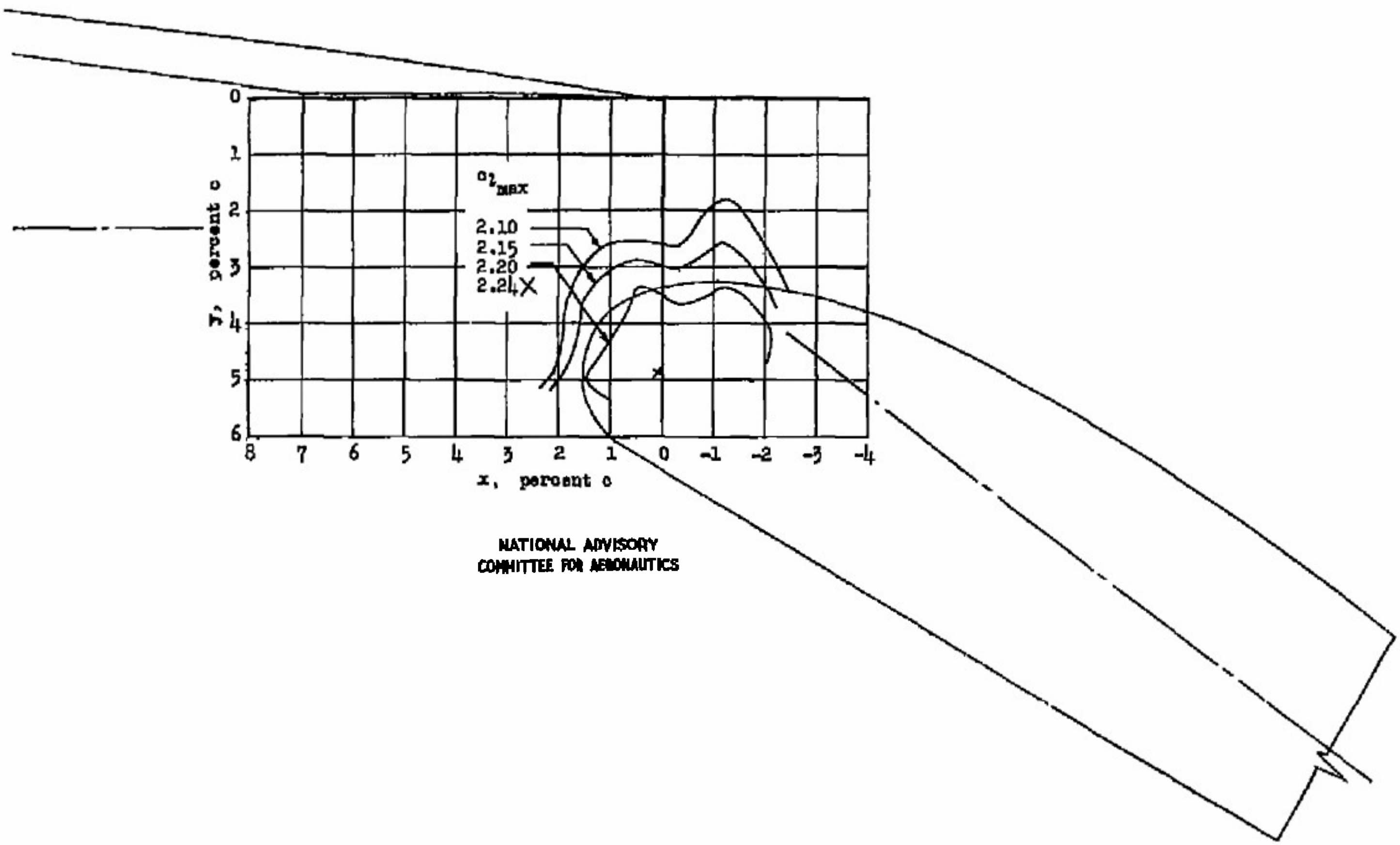


(a) Airfoil with 0.35c slotted flap.

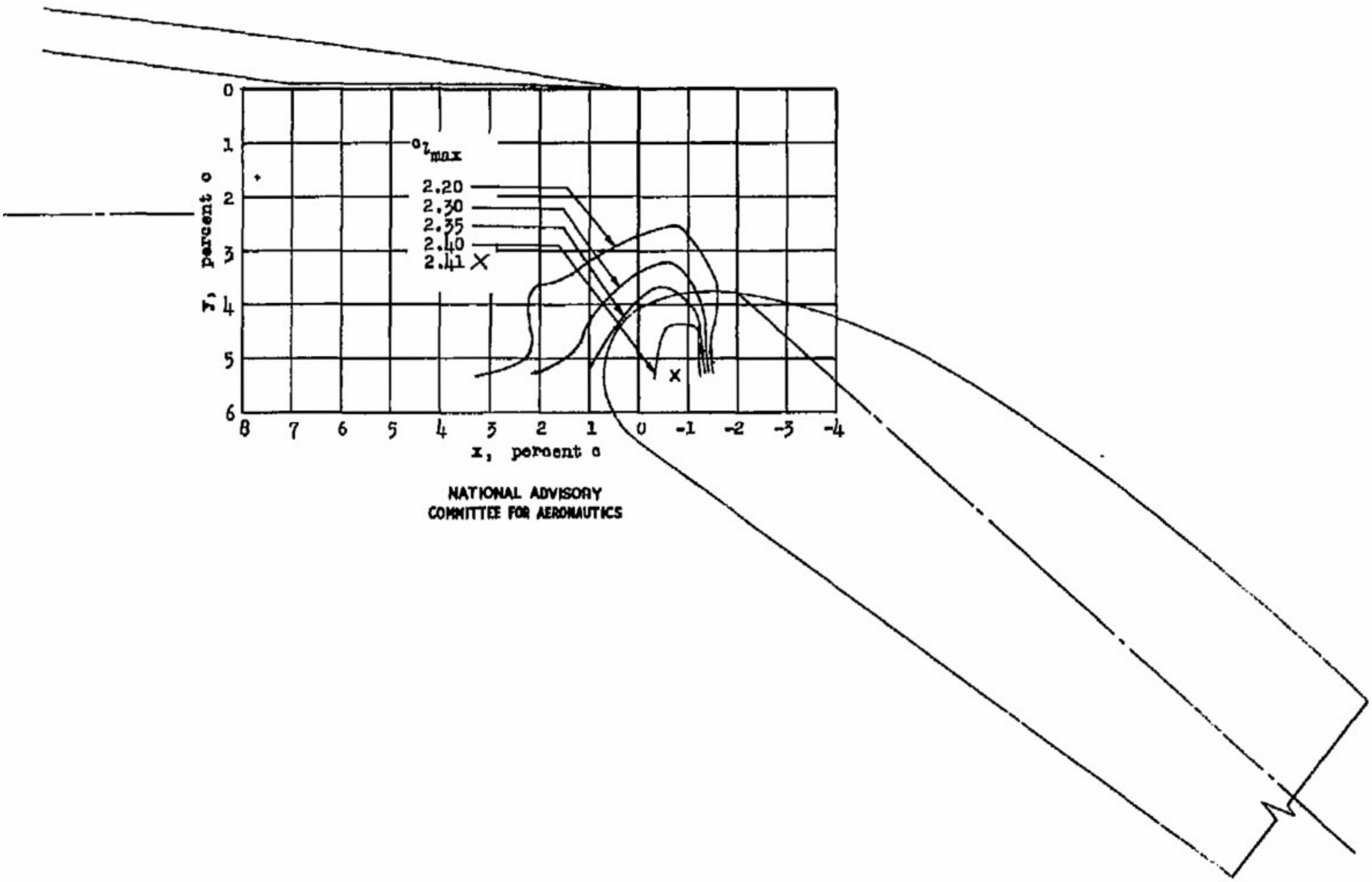
(b) Variables used to define flap configuration.

Figure 1.- Profile of the modified NACA $65_{(112)}$-111 airfoil section with 0.35c slotted flap.



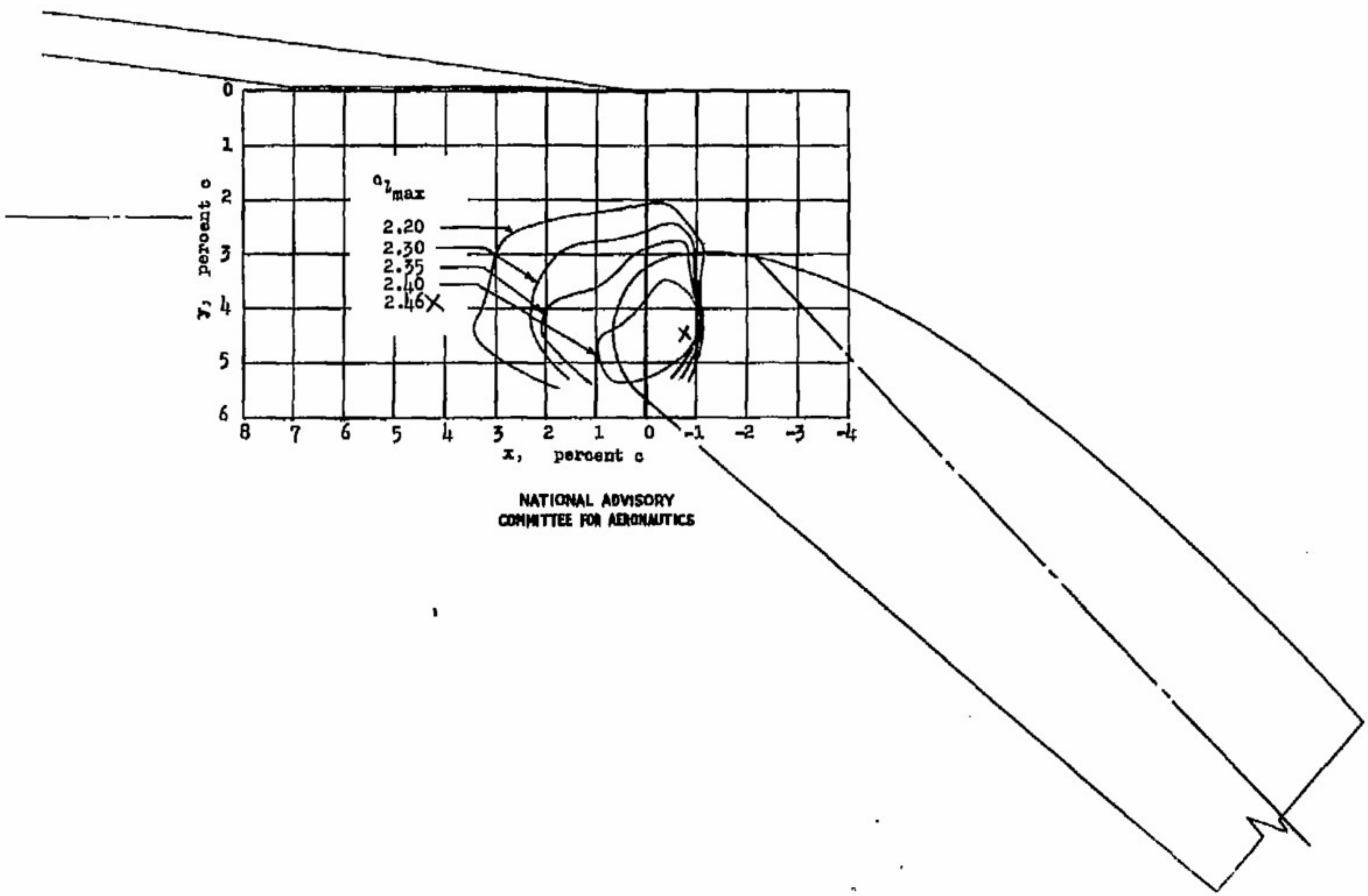
(a) $\delta_f = 35^\circ$.

Figure 2.- Contours of values of maximum section-lift coefficient for positions of the flap leading-edge radius with respect to slot lip. 0.35c slotted flap; modified NACA $65_{(112)}$-111 airfoil; $R = 2.4 \times 10^6$ (approx.).



(b) $\delta_f = 40^\circ$.

Figure 2.- Continued.



(c) $\delta_f = 45°$.

Figure 2.- Concluded.

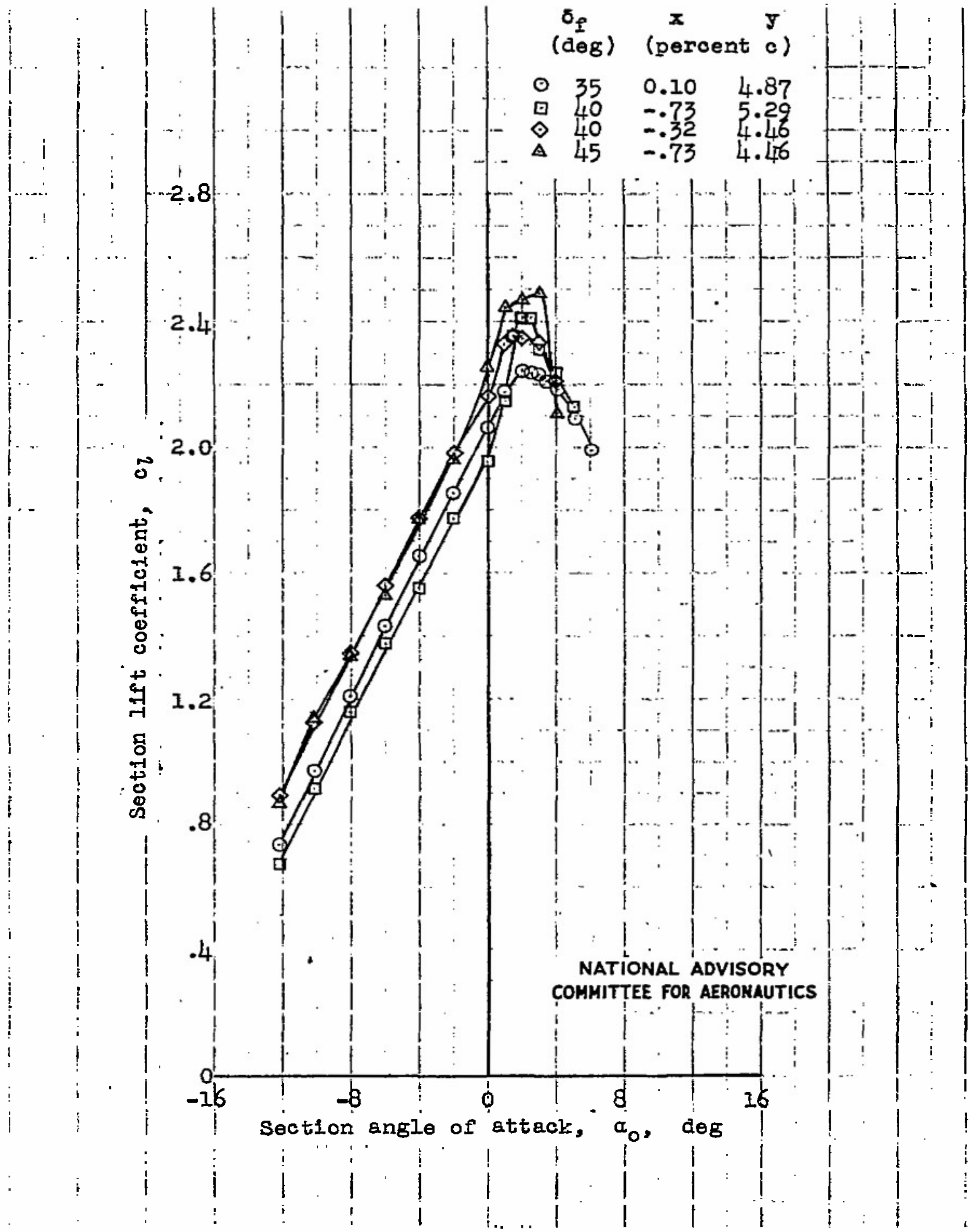


Figure 3.- Section lift characteristics of the modified NACA 65(112)-111 airfoil section with a 0.35c slotted flap. $R = 2.4 \times 10^6$

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